Soil & Tillage Research, 26 (1993) 1–9
Elsevier Science Publishers B.V., Amsterdam

Paratill effects on loosening of a Torrertic Paleustoll*

Paul W. Unger
United States Department of Agriculture (USDA), Agricultural Research Service, Conservation and Production Research Laboratory, P. O. Drawer 10, Bushland, TX 79012, USA

(Accepted 18 September 1992)

ABSTRACT

Unger, P.W., 1993. Paratill effects on loosening of a Torrertic Paleustoll. *Soil Tillage Res.*, 26: 1–9.

Paleustolls occur on extensive areas of the central and southern Great Plains of the USA. These soils are characterized by a thick argillic horizon or, more commonly, a clayey horizon with an abrupt upper boundary. They are slowly permeable and plant rooting in them is limited because of dense B horizons. Paleustolls, which are Mollisols, have characteristics similar to other Mollisols and some Vertisols, both of which occur on extensive areas throughout the world. Hence, practices applicable to Paleustolls should be applicable also to the other soils. Using a Paratill® loosens a soil without causing major cloddiness and retains surface residues that aid soil and water conservation efforts. This study was conducted to determine the cross-sectional area of a Torrertic Paleustoll loosened by Paratill operations performed at shallow (0.15 – 0.20 m) or deep (0.25 – 0.30 m) depths at normal (0.6 m) or wide (0.8 m) point spacings with a four-point implement in relatively wet and relatively dry soil. Soil water content at the different times of using the Paratill did not affect areas of loosened soil. The cross-sectional area of loosened soil below the original soil surface was least (0.412 m^2) with the normal spacing, shallow depth treatment. When the Paratill was operated deeply, the area of loosened soil beneath the original surface was similar with normal and wide point spacings (0.519 and 0.491 m^2, respectively). The total resultant loosened soil area also was similar with deep Paratill passes at narrow and wide spacings (0.763 and 0.788 m^2, respectively). However, when adjusted to a unit width of loosened soil, the loosened area was 32% less with wide point spacing than with normal point spacing for the deeper operation of the Paratill. The normal spacing, deep Paratill treatment resulted in the greatest calculated water equivalency of pore space in loosened soil, namely, 130 mm in the area below the original surface and 191 mm for the total area, which could be of major value for improving water conservation and crop rooting in this soil.

Correspondence to: P.W. Unger, United States Department of Agriculture (USDA), Agricultural Research Service, Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland, TX 79012, USA.
*Paratil® is a registered trade name of The Tye Company, Lockney, TX. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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INTRODUCTION

Paleustolls in the USA occur mainly in the central and southern Great Plains. These soils have a thick argillic horizon or, more commonly, a clayey argillic horizon with an abrupt upper boundary. They may have a petrocalcic horizon. Torrertic Paleustolls occur extensively in the Southern High Plains Major Land Resource Area, which is a sub-region of the southern Great Plains. Most of the Torrertic Paleustolls are cultivated for crop production (Soil Survey Staff, 1975). Torrertic Paleustolls, of the Order Mollisols, have some characteristics similar to other Mollisols and some Vertisols, both of which occur extensively in many regions of the world. Thus, management practices that are applicable to Torrertic Paleustolls should be applicable also to similar soils in other regions.

The dominant Torrertic Paleustolls of the Southern High Plains are the Pullman (fine, mixed, thermic Torrertic Paleustolls) soils, which occur on approximately 1.54 million ha. These soils have a clay loam or silty clay loam surface horizon. Their sub-surface horizons are high in montmorillonitic and illitic clays (Taylor et al., 1963). They are slowly permeable and crop rooting depth and root proliferation in them are limited, mainly as a result of the dense Bt1 and Bt2 horizons that have a moderate, medium-blocky structure (Unger and Pringle, 1981).

Tillage to depths of 0.40, 0.60 or 0.80 m (Schneider and Mathers, 1970) and profile modification to depths of 0.9 or 1.5 m (Eck and Taylor, 1969) have been found to increase water infiltration, rooting depth and root proliferation in Pullman clay loam, but these drastic treatments are impractical for dryland crop production. Chiseling to depths of 0.15 – 0.20 m is less intensive, but it often results in an extremely cloddy surface that requires extensive secondary tillage to provide a suitable seedbed. Under dryland conditions, the effects of chiseling also are short-lived because of the low amounts of residues produced and even lower amounts remaining after tillage. An implement that loosens dense soils while still retaining most crop residues on the soil surface is a Paratill (Mukhtar et al., 1985; Wilkins et al., 1986; Busscher et al., 1988).

The Paratill has multiple 25 mm wide legs that are bent at a 45° angle (left legs to right and right legs to left) at 0.685 m below the toolbar and the total ground clearance is 0.94 m. The leg spacing is adjustable and the legs are fitted with chisel points. Adjustable shatter plates above and behind the points provide additional lifting of the soil without inverting it. Because the narrow legs follow rolling coulters that cut the soil surface, few large clods are brought to the surface. A drawing of one Paratill leg is shown in Fig. 1.

Major soil loosening operations, including use of a Paratill, are energy intensive. Each type of soil-loosening implement has a maximum effective working depth, depending on implement leg geometry and soil conditions

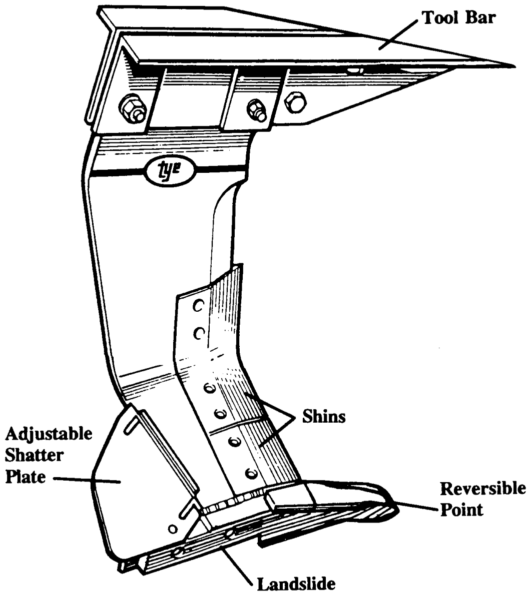


Fig. 1. Drawing of a Paratill leg.

(Spoor and Godwin, 1978; Spoor, 1982). The recommended depth for use of a Paratill is approximately 0.30 m and recommended point spacing is approximately 0.60 m for Pullman soils (The Tye Company, personal communication, 1987). However, if using a Paratill at a shallower depth or at wider point spacings would result in no major differences in soil loosening than the recommended depth and spacing, then the energy requirement could be reduced while still achieving satisfactory loosening of the soil.

This study was conducted to determine the cross-sectional area of a Torrertic Paleustoll loosened by using a Paratill at different depths and point spacings when the operations were performed at different soil water contents.

MATERIALS AND METHODS

This field study was conducted on a Pullman clay loam at the USDA Conservation and Production Research Laboratory, Bushland, TX, in 1988. A Paratill was used in September on a fallowed, relatively wet soil before planting winter wheat (*Triticum aestivum* L.) and in December after dryland grain sorghum (*Sorghum bicolor* (L.) Moench) harvest on a relatively dry soil in an adjacent field. At the time of using the Paratill, the fields had been used for a no-tillage wheat–sorghum–fallow rotation for 8 years. Soil water content distributions at the time of imposing Paratill treatments are shown in Fig. 2. Pullman soil is uniform over extensive areas (Unger and Pringle, 1981). Also,

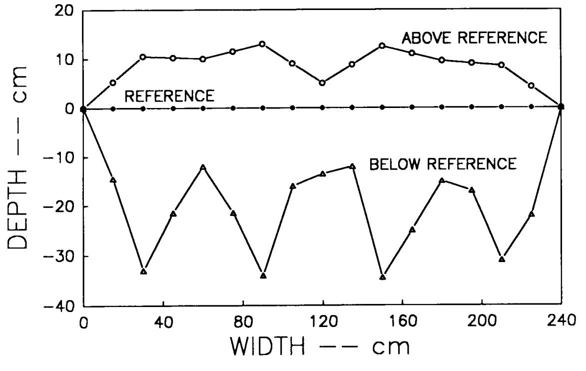
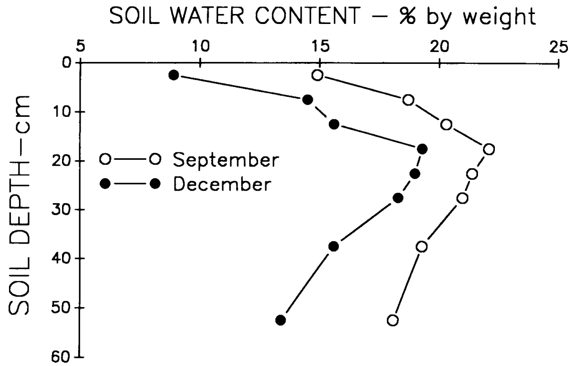


Fig. 2. Soil water contents at the time of using a Paratill on Pullman soil, Bushland, TX, 1988.

Fig. 3. The Paratill used for this study.

sampling for other studies revealed no significant differences in soil properties in the two fields. Hence, soil conditions in the fields at the time of using the Paratill were considered similar, except for soil water contents.

The Paratill treatments evaluated were: NSS, normal point spacing (0.60 m), shallow plowing (0.15 – 0.20 m); NSD, normal spacing, deep plowing (0.25 – 0.30 m); WSD, wide spacing (0.80 m), deep plowing (0.25 – 0.30 m). The Paratill assembly used had four points (Fig. 3), and the speed of operation was approximately 0.9 and 1.8 m s^{-1} for the deep and shallow treatments, respectively. The treatments were replicated three times. For data



Erratum:
The drawings for Fig. 2 and 4 were mistakenly switched. The legends are correct as printed.

Fig. 4. Cross-sectional area of soil loosened by using a Paratill on 'wet' soil in September 1988 to a depth of 0.25 – 0.30 m with points at a normal spacing, NSD treatment.

analysis, the experiment was treated as having a split-plot design, with soil wetness (time of determination) assigned to whole plots and treatments assigned to subplots. This design is valid for testing the treatment effects and the interaction of treatment X soil wetness, but does not provide a valid estimate of error for the whole plot (soil wetness) effects (LeClerg et al., 1962).

After imposing the treatments, trenches deeper than the depth of loosening were dug with a backhoe across the entire width of the zone of soil loosened by one pass of the Paratill. Next, the boundary between loosened and unloosened soil was carefully exposed by hand by removing the loosened soil from above the firm, unloosened soil. Then a cord, anchored at the surface of undisturbed soil at both sides of the Paratill path, was stretched across the path to provide a reference level of the original soil surface. Finally, the cross-sectional area of loosened soil was determined by measuring distances from the reference level downward to the unloosened soil and upward to the loosened soil/air interface. Measurements in September were at 0.15-m intervals while those in December were at 0.10-m intervals. A typical cross-sectional area of loosened soil is shown in Fig. 4. Although the target depth of soil loosening was 0.30 m, loosening occurred to a slightly greater depth, probably because of surface irregularities and uneven fracturing of the soil.

The cross-sectional areas of loosened soil were plotted to scale, and areas beneath and above the reference level as well as total areas of loosened soil were determined from at least five measurements with a planimeter. Data were analyzed by the analysis of variance technique (SAS, 1984). When significant at the 0.05 level of probability, means were separated by the protected least significant difference (Prot. LSD) procedure.

RESULTS AND DISCUSSION

The soil surface heaved 10–20 cm owing to the loosening and lifting action caused by operation of the Paratill. When averaged across treatments, the beneath original-surface, above original-surface and total cross-sectional areas of loosened soil were similar for both wetness conditions, namely, wetter soil in September or drier soil in December (Table 1). However, mean treatment effects were significant for all areas and the treatment × soil wetness (T × SW) interaction was significant for the above surface and total cross-sectional areas.

Beneath the original surface, the area of loosened soil was less for the NSS treatment than for the NSD and WSD treatments, as would be expected. Areas were similar for the NSD and WSD treatments. Although not significant, the trend toward a greater area loosened with the NSD than with the WSD treatment is attributed to greater fracturing of soil between the points with the narrower spacing. Similar results were shown by Spoor and Godwin (1978). When the points were set at the wider spacing, peaks of unloosened soil were less than 10 cm from the original surface. At the narrower point spacing, peaks

TABLE 1

Cross-sectional areas of loosened soil resulting from using a four-leg Paratill on a 'wet' soil in September and a 'dry' soil in December 1988, Bushland, TX

Zone of determination	Time of determination	Treatment[1] (cross sectional area (m^2))			
		NSS	NSD	WDS	Mean
Below original surface	September	0.417	0.496	0.510	0.474
	December	0.406	0.542	0.471	0.473
	Mean	0.412	0.519	0.491	-
	Prot. LSD[2] (0.05 level) for significant effects: treatment = 0.033				
Above original surface	September	0.241	0.207	0.264	0.237
	December	0.220	0.280	0.330	0.277
	Mean	0.231	0.244	0.297	-
	Prot. LSD (0.05 level) for significant effects: treatment = 0.031, treatment × time of determination = 0.087				
Total	September	0.658	0.703	0.774	0.712
	December	0.626	0.822	0.801	0.749
	Mean	0.642	0.763	0.788	-
	Prot. LSD (0.05 level) for significant effects: treatment = 0.053, treatment × time of determination = 0.141				

[1]Treatments were: NSS, normal spacing (0.6 m), shallow plowing (0.15–0.20 m) tillage; NSD, normal (0.6 m) spacing, deep plowing (0.25–0.30 m) tillage; WSD, wide (0.8 m) spacing, deep plowing (0.25–0.30 m) tillage.

[2]Protected least significant difference.

were 13 cm and 20 cm below the original surface in the wetter and drier soils, respectively (data not shown).

The area of loosened soil above the original surface was greater for the WSD treatment than for the NSS and NSD treatments, for which these areas were similar. The greater area of loosened soil with the WSD treatment is attributed to relatively little overlapping of the zones of action of the legs during the Paratill operation. Thus, more of the loosened soil was moved above the level of the original soil surface. The T $\times$ SW interaction was significant because the NSD and WSD treatments increased the loosened area more in the drier soil in December than in the wetter soil in September. For the NSS treatment, soil water content at the time of the Paratill operation had only a slight effect, possibly because the water content near the surface was relatively low at both times (Fig. 2).

The total area of loosened soil was greater for the NSD and WSD treatments than for the NSS treatment. This is attributed to the combined effects of the deeper loosening and the increase in loosened area above the original soil surface.

Although areas of loosened soil were similar for the NSD and WSD treatments based on total width of operation, the area of soil loosened per unit implement width was less with wider than with narrower point spacing. The total width of loosened soil was approximately 2.50 m at the normal setting and approximately 3.30 m at the wide setting. Thus, considering the similar cross-sectional areas of loosened soil for the NSD and WSD treatments, actual area loosened within a given width increment was approximatley 32% less with wide than with normal point spacing. This difference could affect the capture of runoff water and, hence, soil water storage.

Soil bulk densities were not determined for this study. However, the bulk density of no-tillage Pullman clay loam ranges from approximately 1.40 to 1.50 Mg m^{-3} at the 0.0 – 0.3 m depth (Unger and Pringle, 1981; Unger and Fulton, 1990). To calculate the pore volume available for storing water in loosened soil without considering water flow into unloosened soil, an average bulk density of 1.46 Mg m^{-3} was assumed for the soil before using the Paratill. Using this value, along with the cross-sectional areas of loosened soil beneath the original surface and of total loosened soil, the bulk densities after using the Paratill were calculated as shown in Table 2. From these densities and an assumed particle density of 2.65 Mg m^{-3}, porosities within the loosened soil were estimated (Table 2). Also calculated from data in Table 1 were the mean depths of loosened soil beneath the original surface (Table 2). These values multiplied by the after-Paratill porosities provided an estimate of total pore volume available initially after using a Paratill for storing water without consideration of water flow into the unloosened soil (Table 2).

The estimated pore volume beneath the original surface was equivalent to 98 mm or more of water in all cases. Even greater temporary water storage is

TABLE 2

Paratill effects on bulk density, porosity, and mean depth of water storage potential in loosened Pullman soil, Bushland, TX, 1988

Factor considered	Loosened soil area considered					
	Below original surface			Total		
	NSS[1]	NSD[1]	WSD[1]	NSS	NSD	WSD
Bulk density (Mg m^3)						
Original (assumed)	1.460	1.460	1.460			
After Paratill	0.937	0.993	0.910			
Porosity (m^2 m^{-2})						
Original	0.449	0.449	0.449			
After Paratill	0.646	0.625	0.657			
Mean depth of loosened soil (m)	0.165	0.208	0.149	0.257	0.305	0.239
Water equivalency of pore space in loosened soil (m)	0.107	0.130	0.098	0.166	0.191	0.157

[1]Treatments were: NSS, normal (0.6 m) spacing, shallow plowing (0.15–0.20 m) tillage; NSD, normal (0.6 m) spacing, deep plowing (0.25–0.30 m) tillage; WSD, wide (0.8 m) spacing, deep plowing (0.25–0.30 m) tillage.

possible when considering total loosened soil (Table 2), especially if the Paratill is used on the contours of sloping fields. In the region of occurrence of the Pullman soils, individual rainstorms rarely exceed 100 mm. Thus, with all treatments tested, the zone of loosened soil initially should be adequate to retain all water from precipitation on the land, provided adequate crop residues are on the soil surface to prevent surface sealing. Reconsolidation of the soil with time owing to precipitation and cultural operations, however, would reduce the pore space, and the greater pore space with the NSD treatment seemingly would be an advantage.

An earlier study involving use of the Paratill on Pullman soil (Unger, 1989) showed that soil water contents were similar with different treatments at planting time of grain sorghum, but that operating the Paratill at 0.25 – 0.30 m deep resulted in greater soil water contents at the end of the growing season than operating it at 0.15 – 0.20 m deep. This suggested that soil water conditions were more favorable with the deeper operation of the Paratill throughout the growing season and contributed to the greater grain yields with that treatment. A treatment involving wide spacing of the Paratill points was not included in that study.

Based on the results of this study, deep operation of the Paratill at normal point spacing provided more thorough soil loosening than shallow operation at normal point spacing or deep operation with wider point spacing. Whether more thorough soil loosening would be more beneficial in the long run is not certain because the longevity of these treatments was not evaluated. However, soil reconsolidation occurs with time, and was investigated in another study.

ACKNOWLEDGEMENTS

The author acknowledges the assistance of L.J. Fulton in making the field measurements and in statistically analyzing the data. The paper is a contribution from USDA, Agricultural Research Service, Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland, TX 79012, USA.

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